A METHOD FOR EVALUATING SAR REQUIREMENTS FOR THE TWELFTH COAST GUARD DISTRICT

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ABSTRACT

The general background and the authority for Coast Guard Search and Rescue activities is discussed and a brief introduction to the operation of Coast Guard Search and Rescue is presented. An introduction to model building and Monte Carlo Analysis follows. Scientific and industrial applications of these techniques and suggestions for Coast Guard usage are given.

The paper develops a methodology for the application of these methods to Coast Guard problems. A model of the Twelfth Coast Guard District Search and Rescue operations and facilities is constructed. The potential use of this model is demonstrated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND STATEMENT OF PURPOSE

The Coast Guard soon after it was founded as the Revenue Cutter Service effected its first assistance case at sea. The assistance was no more than that any mariner would provide to any stricken vessel. In 1873 Congress authorized "winter cruising" off the East Coast as a formally established duty of the Revenue Cutter Service. As the Coast Guard grew in size and function, its rescue activities were constantly expanded until in 1915, with the consolidation of the Lifesaving Service and the Revenue Cutter Service, the modern Coast Guard was born. By Title 14 of the United States Code the Coast Guard was given the responsibility:

> . . . to administer laws and promulgate and enforce regulations for the promotion of the safety of life and property . . . develop, establish, maintain and operate . . . rescue facilities for the promotion of safety on and over the high seas and waters subject to the jurisdiction of the United States.[1]

The Coast Guard has expanded its activities in two basic areas to carry out these responsibilities. The first area includes the extensive aids to navigation program which

[1]United States Code, Title 14--Coast Guard Chapter 1, Section 2 Volume III, 1958 Edition (Washington: Government Printing Office, 1959), p. 2286.

has established modern visual and electronic navigational systems throughout the world. The prevention of accidents is carried out through regulations concerning the equipment of vessels, the establishment of an extensive merchant marine inspection program, licensing of operators of all vessels carrying passengers for hire and inspection of pleasure craft for safety devices.

Coast Guard activities for the preservation of life and property at sea involve providing assistance to those who, despite preventive measures, have become involved in situations which require assistance. These search and rescue activities, which are the subject of this paper, have been extended beyond the basic area described by the United States Code to include aid to all persons and property at sea at any place where Coast Guard facilities are available. Under the National Search and Rescue (SAR) Plan the Coast Guard is assigned the responsibility for organizing and coordinating the SAR facilities of all Federal and local agencies into a single network with the Maritime Region.

The Maritime Region is divided into two major areas, the Atlantic and Pacific Maritime Regions. The regions are further divided into sub-regions which are in turn, further sub-divided into SAR Sectors. The SAR Sector considered in this study is the San Francisco SAR Sector. This Sector is

comprised of the ocean area bounded by a line from the California coast at latitude 34°-58' North (mouth of Santa Maria River) southwesterly to latitude 24°-15', longitude 134°-00' West thence northwesterly to latitude 40°-00' North, longitude 150°-00' West, thence easterly to the California-Oregon state line. The Commander, Twelfth Coast Guard District is the SAR Coordinator for the San Francisco SAR Sector of the Eastern Pacific sub-region.

The SAR Coordinator has agreements with federal, state, local, and private agencies for providing the maximum practicable cooperation of such agencies and for the use and coordination of facilities committed to SAR missions. The SAR Coordinator is also responsible for carrying out the United States' International Civil Aviation Organization (ICAO) obligations within his area.

The SAR Coordinator's primary responsibilities are defined as follows:

1. Prompt dissemination to interested commands of information about a distress incident requiring SAR assistance.
2. Prompt dispatch of appropriate and adequate facilities.
3. Thorough prosecution of SAR operations until rescue has been effected or until it is apparent that further efforts would prove to no avail.[2]

[2]National Search and Rescue Manual, CG-308, United States Coast Guard. (Washington: United States Government Printing Office, 1959), pp. 2-6.

In pursuing the complexities of search and rescue, the Sector SAR Coordinator maintains a Rescue Coordination Center (RCC). The RCC is the nerve center of operational control.

Since Department of Defense facilities are only available for use to meet civil needs on the basis on noninterference with military missions, this study will concern itself primarily with the utilization of Coast Guard resources to meet the needs of an offshore maritime incident.

The objectives of this paper are to develop a methodology for evaluation of the effectiveness of Coast Guard activities. Analysis of SAR activities, doctrine, facilities, and operating procedures through model building and Monte Carlo analysis is demonstrated. This type of decision making tool can be invaluable in permitting high level decision makers to examine and predict the impact of proposed changes upon the entire system before any decision is made. Through these techniques a more efficient and/or effective SAR system could be developed to meet the expanding requirements being imposed upon the present Coast Guard facilities. Although this paper is directed at SAR activities of the Twelfth Coast Guard District, the methodology is applicable to many other operational problems.

The methodology developed in this paper is based upon Monte Carlo analysis placed within the framework of a model of the total search and rescue problem. Disaster at sea is

a random event which can be analyzed from historical data to determine distributions of incidents to be utilized in the Monte Carlo model building.

The phrase "Monte Carlo" analysis is subject to various interpretations. It has been described as the device to studying an artificial stochastic[3] model of a physical or mathematical process. Monte Carlo has also been used to describe any procedure which involves the use of sampling devices based on probabilities to approximate the solutions of mathematical or physical problems. It has found particular favor in industrial applications where it is used to predict the outcome of a series of events, each of which has its own probability; thereby bypassing the necessity to formulate and solve complicated mathematical equations.

Although the process was known for many years, it was not brought to the forefront until John von Neumann and Stanislas Ulam applied it to the problem of neutron penetration during World War II at the Los Alamos Scientific Laboratory and gave the process the code name "Monte Carlo." The vital question was how far would neutrons travel through various materials. The problem seemed beyond the reach of

[3] A stochastic process involves a probability distribution rather than being constant over space or time.

theoretical calculations; yet experimental trial and error would have been expensive, time consuming and hazardous. Scientists knew most of the basic data for each step but to sum the outcome for such a complicated sequence of events into a practical formula was impossible.

How Monte Carlo analysis was applied to this problem is well described by the following:

> Suppose we want to know what percentage of the neutrons in a given beam would get through a tank of water without being absorbed or losing most of their speed. No formula could describe precisely the fate of all the neutrons. The Monte Carlo approach consists of <u>pretending</u> to trace the life histories of a large sample of neutrons in the beam. We imagine the neutrons wandering about in the water and colliding occasionally with a hydrogen or oxygen nucleus. We shall follow our neutrons one by one through their adventures.
>
> We know the average distance a neutron will travel before it encounters a nucleus and the relative chances that the neutron will be absorbed by the nucleus or bounce off. Let us take a neutron and follow its life history. It is a slow moving neutron and its first incident is a collision with a hydrogen nucleus. We know that the chances are 100 to one that the neutron will bounce off from such a collision. To decide what it will do in this instance, we figuratively spin a roulette wheel with 100 equal compartments marked "bounced off," and one marked "absorbed." If it says "bounced off," we spin another appropriately marked wheel to decide what the neutron's new direction is and how much energy is lost. Then we must spin another wheel to decide how far it travels to the next collision and whether that collision is with a hydrogen or oxygen nucleus. Thus we follow the neutron until it is absorbed, until it loses so much energy that it is no longer of interest, or until it gets out of the tank. We go on to accumulate a large number of such histories and obtain a more or less precise figure for the percentage of

neutrons that would escape from the tank. The degree of precision depends on the number of trials.[4]

By a similar analysis the operation of a buoy tender performing routine servicing of an aids to navigation system could be programmed and the time to service a series of aids predicted.[5] As the tender proceeds from its depot the time to reach the first aid is easy to predict based upon speed and distance. Weather has an insignificant influence inasmuch as most servicing is performed under good operating conditions. When the tender reaches its first aid the time involved is dependent upon the type of aid, the delays in maneuvering to pick up the buoy, the time to rigging the buoy and the nature of the servicing required. Each of these events occurs in a random manner.

As in the neutron example the tender travels between points of delay. Aids to be serviced are similar to the nucleus. The probability of certain events occurring at this encounter are known and by the use of Monte Carlo simulation, what will happen at each encounter can be predicted. The tender, or neutron, then proceeds to the next delay

[4]Daniel D. McCracken, "The Monte Carlo Method," Scientific American, May 1955, pp. 90-91.

[5]John G. Martinez, "Simulation of an Aids to Navigation System" (unpublished Master's thesis, United States Naval Postgraduate School, Monterey, 1961).

point and again encounters various known probabilities of what will happen. As the tender proceeds to service a series of aids, the time at each aid varies in a random fashion. The length of time it will take to service a series of aids can be predicted using Monte Carlo analysis. The success of this method depends upon the ability to generate thousands of cases from which predictions of how the system will behave in the long run can be made.

The above applications of Monte Carlo consist of choosing the probability process and generating sample values of the random variables. In practice, random numbers are used instead of roulette wheels to determine, according to some probability, the outcome of an event. The use of the modern high speed computer has made the method particularly attractive.

Accuracy improves only as the square of the number of trials. If it takes 10,000 trials in order to obtain accuracy to the nearest tenth then it is reasonable to expect $(10,000)^2$ trials for accuracy to the nearest hundredth. Fortunately, most industrial problems do not require this kind of accuracy. The decision maker usually needs to know relative values and roughly what will happen as a result of alternative events.

Industry has found Monte Carlo analysis useful in solving problems ranging from scheduling, maintenance and

quality control to sales and product distribution. The future is always clouded with uncertainty. This uncertainty can be reduced for the decision maker by using Monte Carlo to simulate future sequences of events and thus test various alternate plans on paper without disturbing the physical process. In the event probability distributions of the event or events to be analyzed are not available, the historical frequency of past events may be utilized. In the absence of such percentages, the decision maker may have some feeling or subjective judgment which can be used to construct a model from which indications may be obtained as to where to expend resources for more accurate data. In another situation, the initial probabilities and the end results may be known, but it is desirable to have some idea of what happens in between. In this case, various probabilities may be assumed for the unknown event and the problem run repeatedly until the initial and terminal quantities are brought into correspondence by some intermediate probability or probabilities. It is possible for more than one distribution to satisfy the model.

To better understand the ramifications of the Monte Carlo method a hypothetical and overlysimplified industrial problem,

illustrating how the method enables management to make decisions for scheduling maintenance at least cost, is presented.[6]

A manager of a paint department which coats metal parts with baked enamel is faced with a problem of scheduling repair of oven heating elements. Both ovens in the plant contain three heating elements which are subject to failure at some unknown time. If one or more heating elements fail in either oven that oven becomes inoperable during the repair period. If failure should occur so that both ovens are down at the same time, there will be a production bottleneck.

Several alternative maintenance policies are to be evaluated. Using historical heater life data the percentage of heating element failures for any given interval of operating days can be calculated. When one heating element fails all elements could be replaced or only that element which failed. In addition the life of the remaining elements could be considered and those elements which have lasted beyond the average operating life of an element could be replaced. Repair time for replacing one element is three days, two elements require five days and all three elements require six days for replacement.

[6] Paul Green, S. Reed Calhoun, and I. Landis Haines, "Solving Your Plant Problems by Simulation," Factory, February 1959, pp. 80-86.

A series of three two-digit random numbers are used to designate element lives in the first oven. Since the oven is inoperable when one element fails, the smallest random number indicates which of the three elements failed first. Using the probability distribution, it is then possible to simulate how many days the oven operated before failure. Next, a series of random numbers are selected from the random number table for elements in the second oven. The process is repeated over and over again.

By generating data for several years, the average yearly values for the number of repairs and days lost for repairs can be determined for each of the policies under consideration. Average repair policy costs depend on the relative costs of the elements, production lost, and maintenance labor.

This simple example illustrates how random numbers can be used to solve real world problems which depend in some way on probabilities. What is a least cost policy for one mode of operation may not be for another.

Comparable industrial applications could be developed to assist Coast Guard decision makers in establishing spare parts requirements, maintenance procedures, and schedules. For example, a patrol boat is down for maintenance due to a main engine bearing failure. Would replacement of all bearings at the present time require less maintenance down time

and lower total costs? Would replacement of rings, connecting rod bearings, etc., at the same time reduce total vessel down time? These actions can be simulated by the adaptation of the Monte Carlo techniques discussed in this paper. The use of such techniques can provide significant data for decision makers.

By the same procedures one could simulate the operation of a complex buoy and determine the service frequency and the specific components which should be replaced at each servicing. Present procedures are based upon judgment and past experience. Analytical techniques are required to insure that the present methods are the best, not simply adequate.

Monte Carlo is like any other simulation model. Degrees of simplification or realism are possible depending upon availability of data and the sensitivity of the solution to small changes in the model. Monte Carlo is descriptive rather than analytical. In other words, rather than employ mathematics to represent a general solution it approximates the answer systematically by running the simulated process a large number of times with the alternates under test. This way, the data in a sense "speak for themselves."

Since Monte Carlo depends on a large number of trials of a repetitive nature, its use usually presupposes the

availability of a computer. However, even with such assistance, difficulty is sometimes encountered when the investigator is interested in a random walk of rare occurrence. An inordinate amount of cases must be generated to produce the rare event. There are methods of biasing the sampling to produce more rare events per total cases generated then would normally occur. The interested reader will find efficiency methods discussed in technical journals and is so referred. [14, 15]

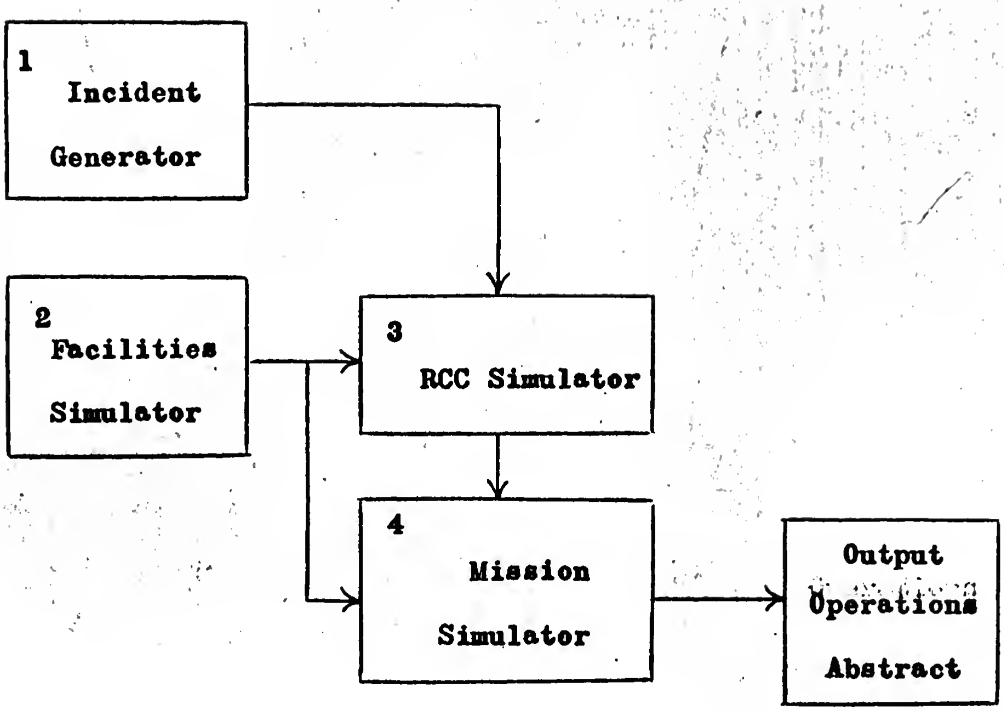
The Monte Carlo method holds great promise for a wide variety of problems. The investigator may not have any criterion of success in mind when he builds a model but may be interested in studying the behavior of a system. He may never be able to say what is optimal, only that one system or way of doing things is better than another. The business man can say which system is best by using dollars as a measure of effectiveness. The Coast Guard is not a profit making organization. It purchases resources with dollars and in turn uses these resources to save lives and property. Chapter II will construct a model which can determine the lives and property saved with alternative mixes of resources.

CHAPTER II

THE CONSTRUCTION OF A SEARCH AND RESCUE MODEL

To demonstrate the potential value of more sophisticated analytical techniques as applicable to Coast Guard decision making procedures, a model of the Search and Rescue facilities of the Twelfth Coast Guard District was constructed. The model makes it possible to evaluate Coast Guard SAR effectiveness and to conduct cost effectiveness analysis. The analysis provides bases for better budget and procurement decisions by assisting in measuring and evaluating SAR doctrine and facility and location requirements.

The complete SAR model is shown in Figure 1,page 15. Gaming techniques and Monte Carlo analysis can generate a series of SAR incidents, assign units to conduct indicated action and provide operational summaries. As constructed the model consists of five sub-models which simulate separate areas of the search and rescue problem. The first section of the model is the incident generator. This section uses Monte Carlo techniques based upon the analysis of historical data to simulate a series of SAR incidents. The second portion of the model is the facilities section which can be programmed to represent the facilities available, their location, operating capabilities and limitations.



[1]Develops series of SAR incidents.

[2]Provides fixed input of present facilities or alternative facilities capabilities of each facility.

[3]Evalutes each incident and assigns units to case.

[4]Simulates each SAR mission, hours under way, and type of vessel.

Figure 1

SAR SYSTEM MODEL

The outputs of these two sections provide data to the decision section, the RCC simulator. Programmed with a series of decision questions based upon SAR doctrine and facilities capabilities, this section evaluates each incident and assigns appropriate facilities to conduct the required operations. The assigned facilities then conduct the SAR mission within the criteria established in the mission simulator. The output of the mission simulator provides a summary of operating activities for the incident and the system under evaluation. The effectiveness of the system and facilities is indicated. Combined with accounting data, it provides a cost effectiveness evaluation of the system.

The Incident Generator. The incident generator is a model employing Monte Carlo techniques to simulate the present coastal and oceanic search and rescue problem confronting Commander, Twelfth Coast Guard District. As presented, the model represents the months of greatest SAR activity: July, August, and September. With modifications of input the same methodology can be used to simulate any time period, place or case load. The model first generates the daily environmental conditions and forecast and the number of cases. Then time of receipt of incident information and the interdependent variables, position, type of unit in distress and its nature are produced. The incident generator has been kept simple

yet reasonably realistic. Statistical data upon which this section of the model is based is tabulated in the Appendix.

The elements comprising environmental conditions were limited to visability, wind, and sea state. The District coastline was divided into three subareas, Oregon-California border to Point Arenas, Point Arenas to Point Sur, and Point Sur to Point Arguello. Although environmental conditions vary along the California coast, they can be considered the same within the subareas. Considering only the summer months, examination of historical data revealed even this level of sophistication unnecessary. Virtually the same conditions prevail throughout the District during the summer season.

A weighted average per cent of restricted visability was computed from hours in operation of selected coastal fog signal stations. Thirty-two per cent fog proved an adequate approximation for the District. This figure is too high for offshore and rather low for the Eureka and Point Reyes areas. North of Cape Mendocino average hours of summer small craft warnings were 118 or just under five per cent. South of Point Sur the average hours were ten. The weighted District average was only two per cent. Wind force was therefore disregarded. A summary of the environmental conditions assumed is presented in Table XII, page 69, of the Appendix.

A seasonally adjusted sea condition distribution was calculated (Figure 2, page 19) from historical frequencies of annual wave heights due to both distant, an important factor, and local storms. Ranges of zero to three feet, three to ten feet, and over ten feet were incorporated in the model. Weather forecast was taken as the environmental conditions generated for the next day. The simplification of reducing summer environmental conditions to visability and sea conditions for the entire District probably could not be justified for other periods. Each area would need its weather and sea conditions separately generated. Also, any extraordinary local conditions were ignored with the assumption they would be considered in the final solution.

The number of Twelfth Coast Guard District SAR cases in the first quarter of fiscal year 1964 was 1,042 of which 388 were classed as coastal. The remainder were in San Francicso Bay, the Sacramento River and its delta, and Lake Tahoe. The mean coastal cases per day was 4.2. About twice as many incidents occur on a Saturday, Sunday, or holiday than on a weekday. Assuming a two to one ratio for the 28 holidays and 64 weekdays, the means are 6.6 and 3.3, respectively. These means correlate closely with the estimates furnished by the Twelfth Coast Guard District RCC and so were employed in the model. A Poisson distribution about the means also

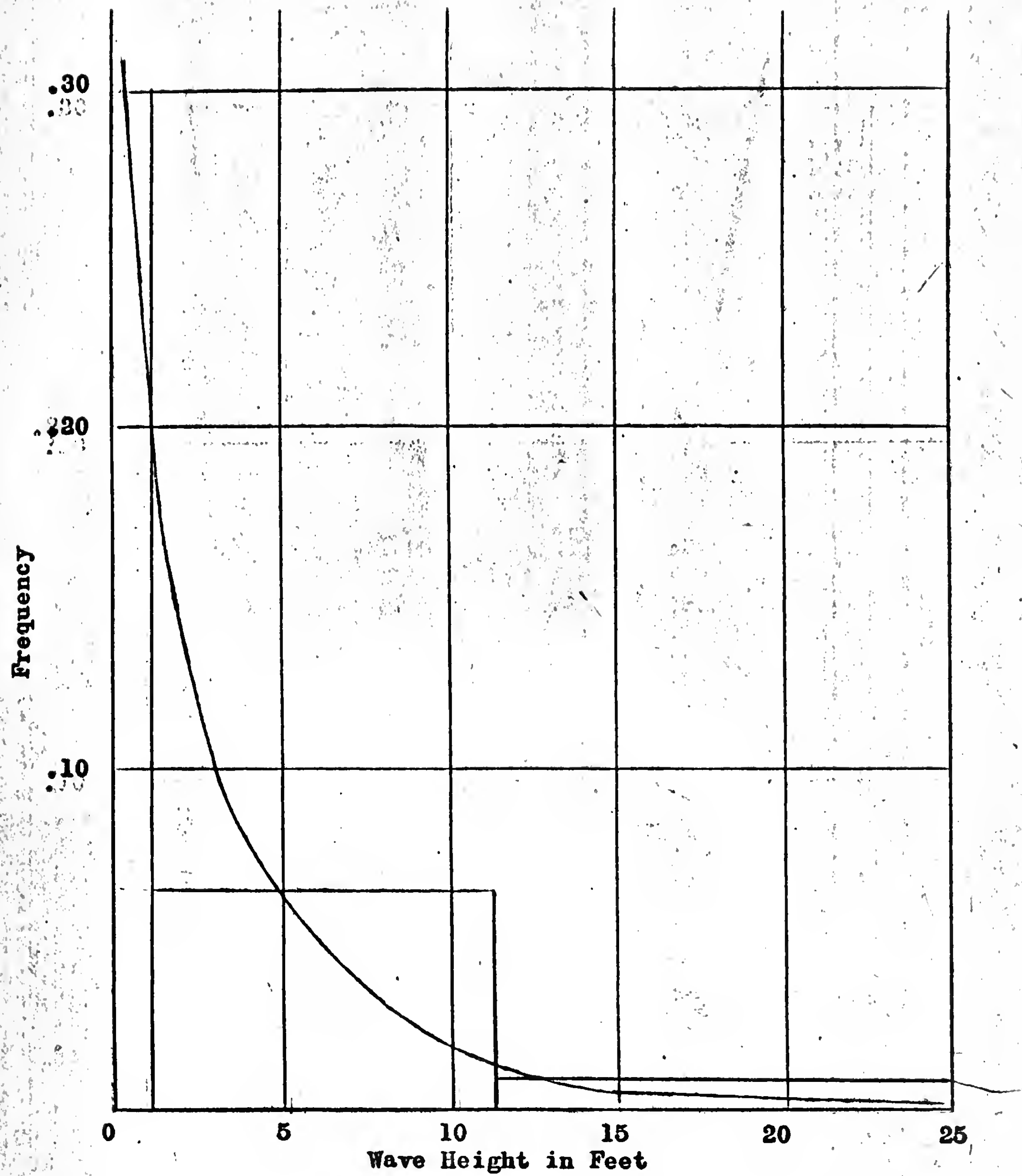


FIGURE 2

AVERAGE WAVE HEIGHTS VS FREQUENCY OF OCCURRENCE
COASTAL WATERS TWELFTH COAST GUARD DISTRICT
JULY THROUGH SEPTEMBER

fitted neatly with the concensus of the staff. The distributions used are shown in Table XIII, page 70, of the Appendix.

To determine whether any serious queuing problems might exist, it was necessary to add time of receipt of distress information to the model. The day was divided into six hour quarters and the concensus of estimated per cent ranges assumed. Table XIV, page 71, of the Appendix gives the resulting distribution.

The remainder of the model was based on the case totals for the period from July through December 1963 and sampling of the Reports of Assistance for fiscal year 1963. Some subjective evaluation and estimation was required because of insufficient data breakdown and double counting found in published figures.

The coastal and oceanic area of the Twelfth District was divided into twenty-one grids. The inshore region comprises the area from the shoreline to twenty miles seaward from 34°-30' North to 42°-North divided into fifteen grids one-half a degree of latitude wide. The offshore regions are divided into six grids. The areas extending from twenty to one hundred miles offshore and over one hundred miles offshore from the Eleventh to the Thirteenth Coast Guard District boundaries are trisected latitudinally by the

thirty-sixth and thirty-ninth parallels as shown in Figure 3, page 22. The positions of the 608 coastal SAR cases of the first and second quarters of fiscal year 1964 were plotted on a so gridded chart and the number in each grid counted. The proportion of each quarter cases in each grid was determined. Only the first fiscal quarter cases were used in the model. The six month and second quarter distributions are included for comparison. Tables XV, XVI, and XVII on pages 72, 73, and 74 of the Appendix are the resulting breakdowns.

The unit assisted or type of assistance as well as nature of casualty is dependent on position. The unit assisted or type of assistance was consolidated into ten categories. Vessels were divided into five classes: less than 26 feet, 26 to 40 feet, 40 to 65 feet, 65 to 100 feet, and over 100 feet. Medical cases were divided into two types: radio advice only and patient removal or treatment. The three other categories were aircraft, personnel only, and miscellaneous which include such cases as flare sightings, false alarms, and shore facility fires. The distributions computed are presented in Tables XVIII, XIX, and XX on pages 75, 76, and 77 of the Appendix. The data from Appendix Table XIX, page 76, first quarter fiscal 1964, were used in the development of the model.

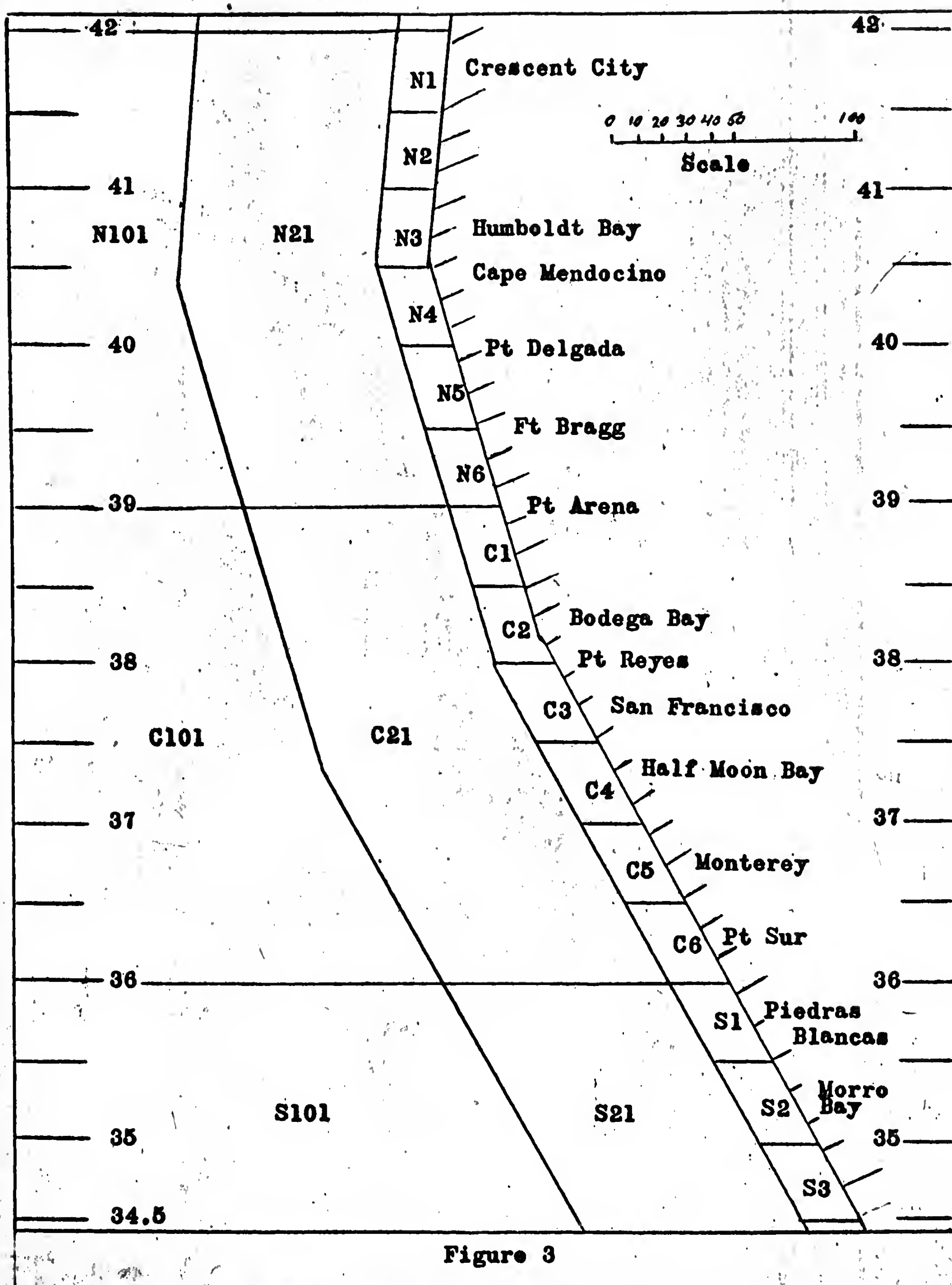


Figure 3

TWELFTH COAST GUARD DISTRICT SAR GRIDS

Nature of distress was reduced to the minimum number of categories. Vessels were considered only as disabled, overdue, aground or foundered. Disabled included mechanical failure, fire, collision, or any like case not requiring immediate assistance. Foundered covered all cases of whatever nature in which immediate assistance was required to save life and/or property from imminent peril. Aircraft incidents were limited to two types. One was of the intercept, escort, or precautionary orbit type. The other was crash or overdue. All aircraft incidents were considered to require immediate assistance. Table XXI, page 78, of the Appendix is a breakdown of nature of distress by distance offshore and vessel size.

Figures 4, 5, 6, 7, and 8 on pages 24 to 28 show the complete incident generator. It is operated by moving from left to right along the lines joining the boxes. The boxes represent an event. Each box is named and for the type or unit in distress and nature of casualty, contains the random number range. Tables XII, XIII, XIV, and XVII on pages 69, 70, 71, and 74 contain the random number ranges for environmental conditions, number of cases, time of receipt of distress information, and incident position. The steps in operating the incident generator are as follows:

1. Set day as weekday or holiday.
2. Obtain a six digit random number.

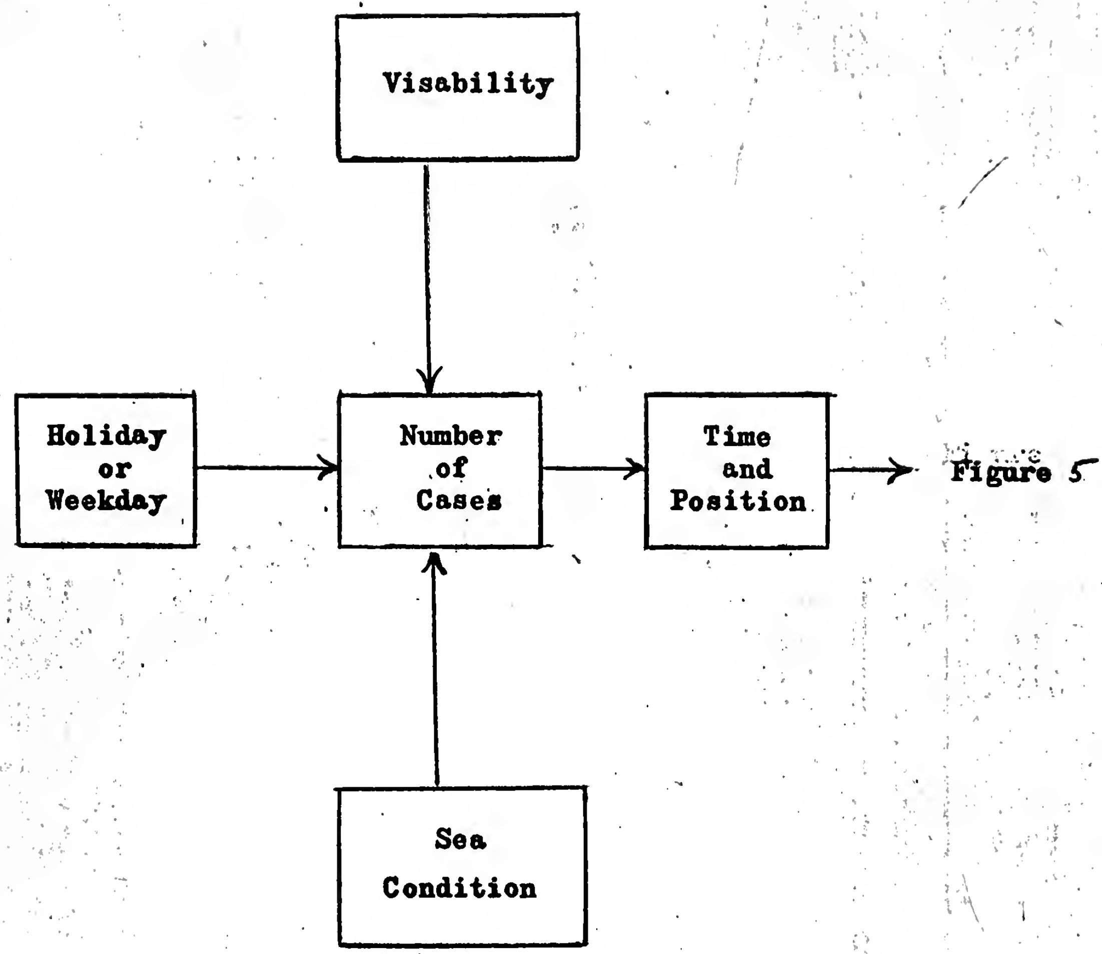


FIGURE 4

DAILY COASTAL SAR ENVIRONMENT SECTION

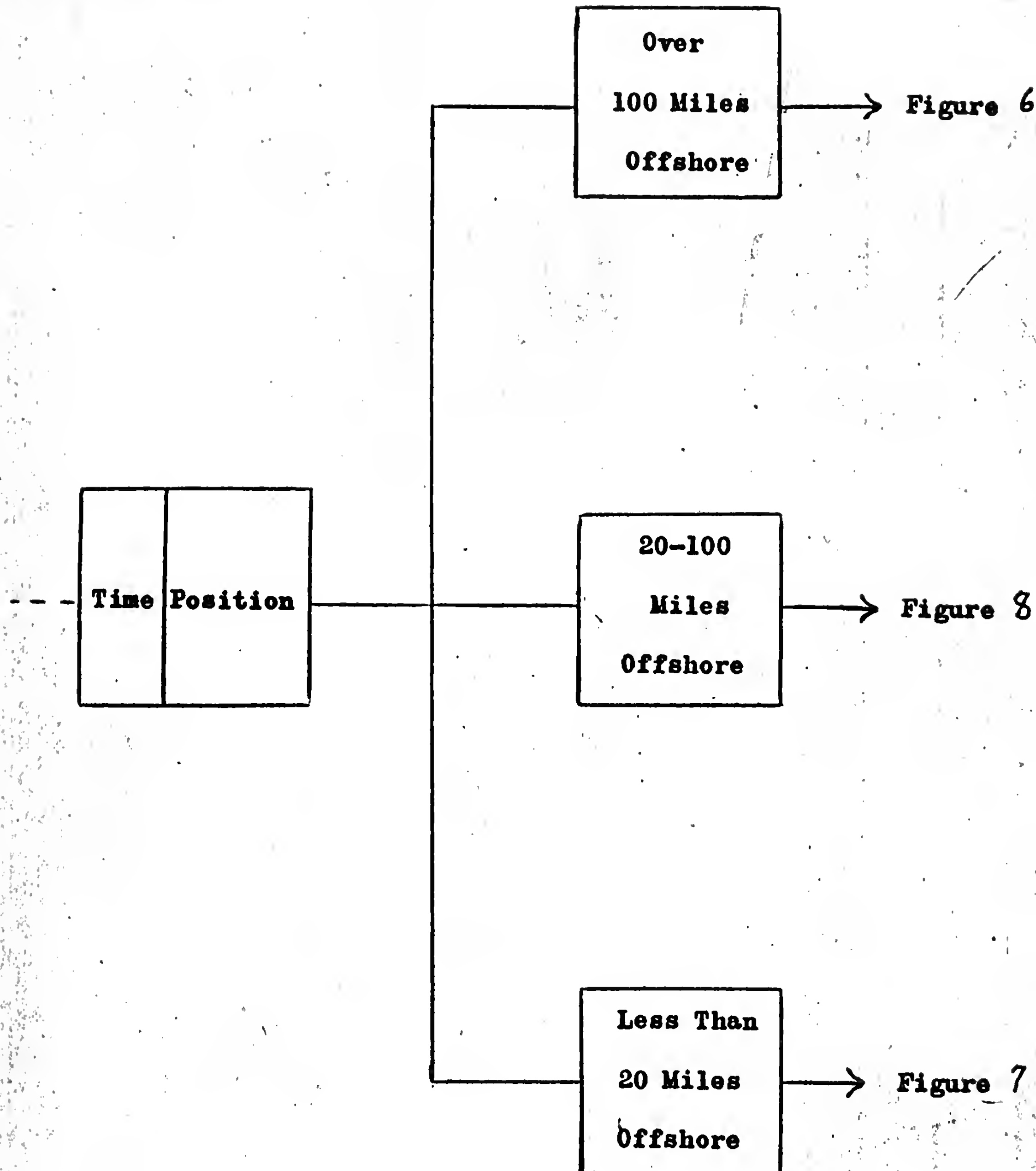


FIGURE 5

SAR INCIDENT POSITION SECTION

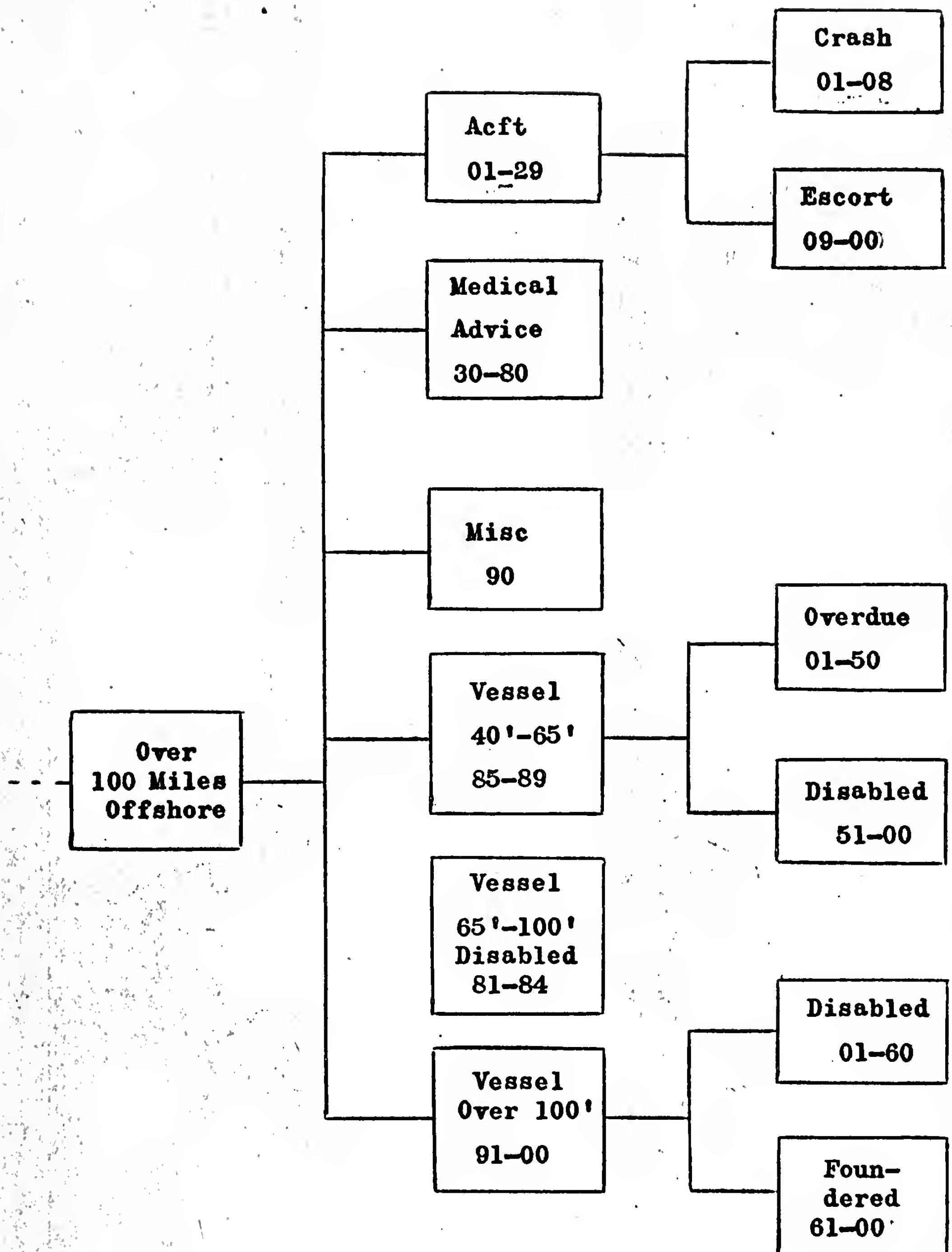


FIGURE 6

RANDOM NUMBER RANGE OF INCIDENT TYPE AND NATURE
OVER 100 MILES OFFSHORE

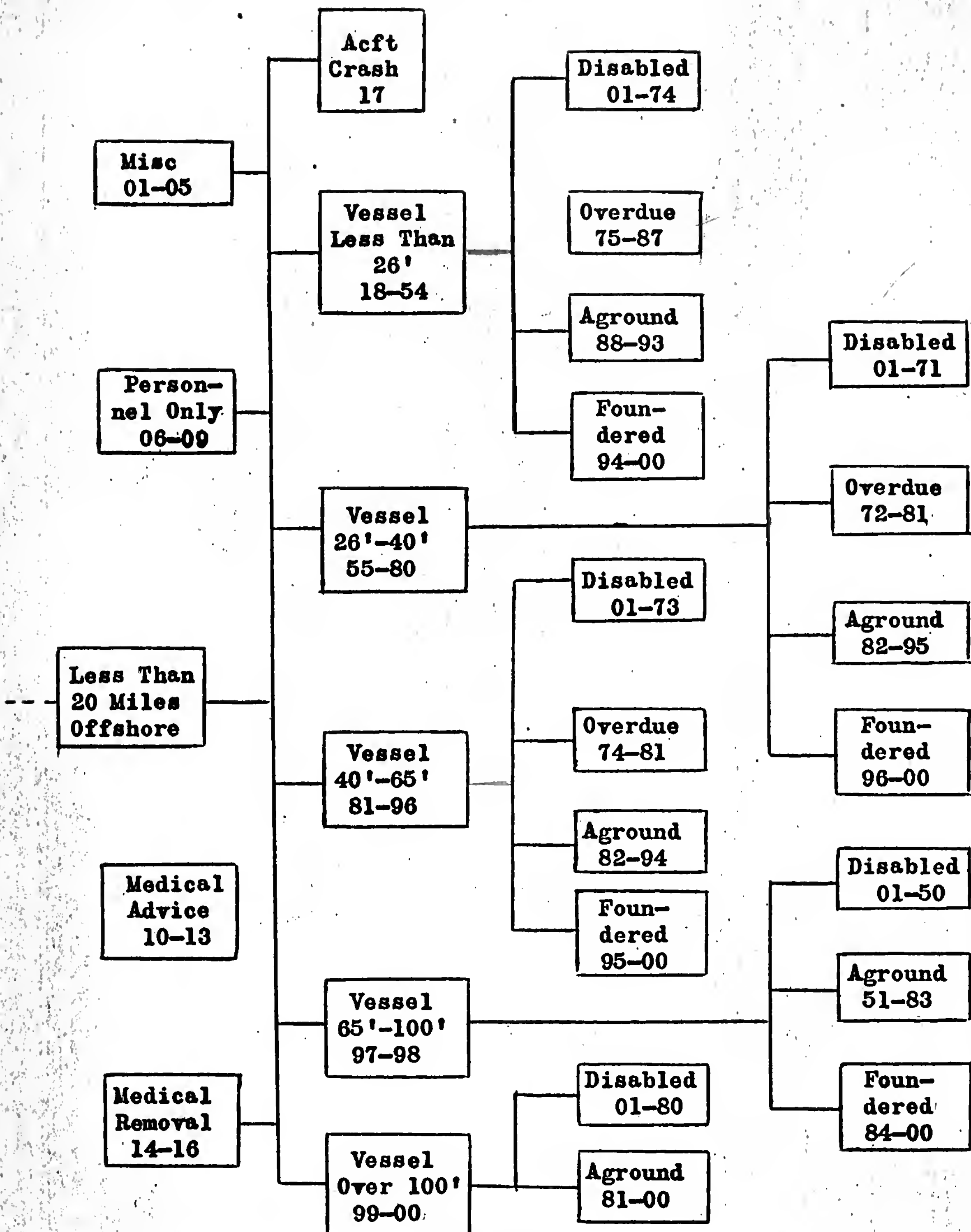


FIGURE 7

RANDOM NUMBER RANGE OF INCIDENT TYPE AND NATURE LESS THAN 20 MILES OFFSHORE

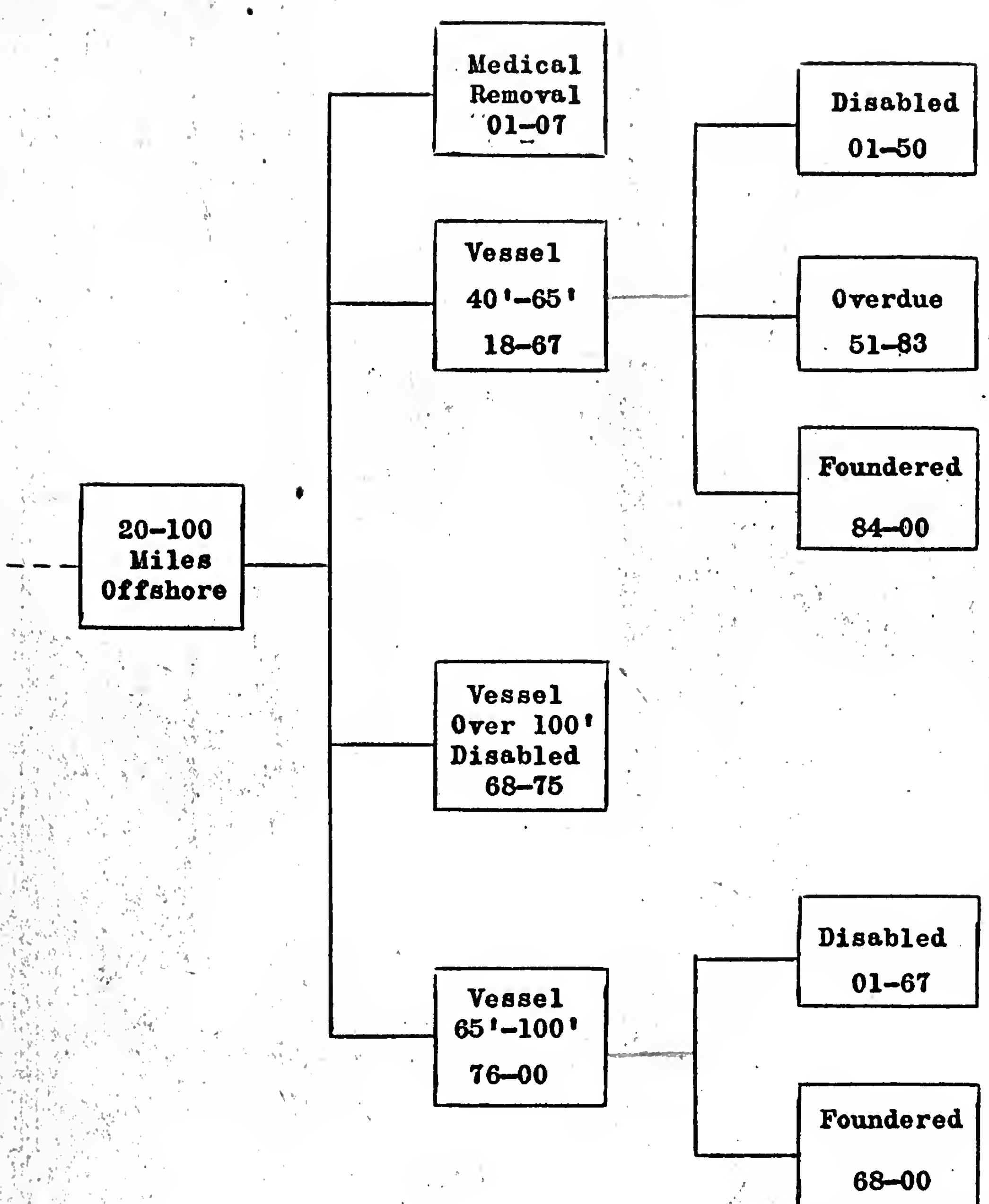


FIGURE 8

RANDOM NUMBER RANGE OF INCIDENT TYPE AND NATURE
20-100 MILES OFFSHORE

3. Consult the appropriate distribution.
   a) The first two digits reoresent visability.
   b) The second pair indicate sea condition.
   c) The last two digits generate number of cases.
4. Obtain a nine digit random number.
5. The first and second digits determine time of receipt of distress information.
6. The third, fourth, and fifth digits are compared with the position distribution to produce grid position.
7. The sixth and seventh digits represent type or unit in distress.
8. Digits eight and nine indicate nature of casualty if required.
9. Steps 4 through 8 are repeated until the number of incidents determined in step 3.c) are generated.
10. The procedure is repeated for as many days as desired.

For an example assume day 16 is a weekday. From the six digit random number 51-13-19 the existing environmental conditions are generated as clear with a 0 - 3 foot sea. Forecast cannot be determined until environmental conditions for day 17 are generated. The number of cases is 2. Next assume the nine digit random number 06-436-85-94 is obtained. This number represents a case between the hours of 0000 and 0600 in grid C3 which is within twenty miles off the Golden Gate. It is a 40 to 65 foot vessel foundering.

<u>The Facilities Model</u>. This section of the total model, which provides a model of the system facilities to be evaluated, presents the least problems in its design. Throughout the evaluation of a series of cases it is considered as fixed. For the purposes of this paper the facilities of the Twelfth Coast Guard District were placed in this section.

To simplify the model, to facilitate its operation, and to insure that only significant variables remain in the model, it was designed to include only those facilities which would be utilized in the assistance of cases in coastal areas. San Francisco Bay and the Sacramento River delta area facilities were not used. This may not be a reasonable assumption. However, it can be justified since, with the exception of aircraft, units servicing the San Francisco Bay would not normally operate outside of the area. The SAR facilities of all Federal Agencies are often accessable to the Coast Guard for the conduct of maritime SAR operation. They have not been included in this model as they are only available when not performing their primary mission.

The model has been further simplified by not including any communications facilities. In actuality the combined communication networks of all military and civil organizations functions as an integrated whole to provide rapid dissemination of information concerning SAR incidents and effective control of resulting operations. This model has assumed that information of an incident is immediately available to the RCC and the communications to control the operation are effective. Communications could be the subject of a separate study utilizing Monte Carlo techniques.

With the information above programmed into the facilities model, the model can show the location and operating characteristics of each operating unit within the District.

Operational status of major vessels is also included in this section of the model by general types and location. For example, of the three high endurance cutters located in San Francisco, one is considered to be deployed in mid ocean, one is on two hour standby, and one is in maintenance status. The two medium endurance cutters at Monterey and Eureka are considered as being on two hour SAR standby at all times. Although not fully realistic, it is a reasonable assumption since when they are not on standby status, another vessel from the District is assigned to their area of responsibility. The time which may be lost in assigning a San Francisco cutter to a task that would normally fall to these vessels should not effect the overall system evaluation significantly.

Small boats are considered to be available at all times. A more comprehensive model could analyze breakdown and maintenance frequencies and through Monte Carlo techniques simulate actual conditions more closely.

The facilities section provides inputs to the decision section for mission assignment purposes and to the mission simulator for developing each mission. It does not take into consideration the fact that a vessel may be already assigned

to another mission. This information is provided by the decision section which has to be programmed to keep track of the status of units it has assigned to various missions.

Although this section of the model is fixed for the evaluation of any given system, it may be modified to compare the effectiveness of alternate facilities, locations, or capabilities. In addition the requirement for new facilities or the reduction of either facilities or the capabilities of units can also be evaluated. To compare the effectiveness of various mixes of facilities and capabilities this section of the model is varied and all others held constant, thus, decisions to satisfy future requirements can be made in a more efficient manner.

Figure 9, page 33, provides a model of the operating characteristics and capabilities of units available in the Twelfth Coast Guard District.

The Decision Section. The decision section, or RCC simulator, functions to make decisions and assign units to SAR missions. It is programmed, acting in place of the RCC Controller, to evaluate each SAR incident as it is reported and, within criteria established, to determine the action required. In addition, this section assigns mission and facility priorities.

Actual Facilities	Model Facilities	Model Operational Specifications
WP6 WAVP	High endurance cutter	Range 20,000 miles. Sustained speed 17 knots. Towing, pumping, fire fighting, and fuel transfer capability
WATA WATF WSC	Medium endurance cutter	Range 5,000 miles Sustained speed 12 knots Towing, pumping, and fire fighting capability.
WPB-95' WPB-82'	Low endurance cutter	Range 1,000 miles Sustained speed 17 knots Tow up to 150 tons
44' MLB	Motor Lifeboat Large	Range 200 miles Sustained speed 16 knots Heavy surf conditions in vicinity of bars on Pacific coast.
36' MLB	Motor Lifeboat Small	Range 150 miles Sustained speed 8 knots Heavy surf conditions in vicinity of bars on Pacific coast.
40' UT 30' UT	Utility Boat	Range 100 miles Sustained speed 20 knots Moderate weather offshore. No surf.
25' MSB	Motor Surfboat	Limited Range Sustained speed 6 knots Heavy weather and surf conditions.
HC-130B	Long Range Aircraft	Search Radius 1,000 miles Sustained speed 300 knots Search endurance 5 hours
HU-16E	Medium Range Aircraft	Search Radius 500 miles Sustained speed 200 knots Search endurance 5 hours
HH-52A	Helicopter	Search Radius 175 miles Sustained speed 90 knots Hover 30 minutes

Figure 9

FACILITIES CAPABILITY MODEL

Through a series of programmed questions, as shown in Figure 10, page 35, it determines the location of the closest facility capable of providing the required assistance. It considers the location, size, and nature of distress as well as the prevailing weather, forecasted weather, and the capabilities of rescue units. A more sophisticated model could also determine the unit which was capable of arriving on scene in the shortest period of time. For the purpose of this initial model this is not considered to make any significant difference in final costs or effectiveness. Seventy-nine per cent of the cases are within twenty miles of shore and the closest facility is generally the one that could arrive first on scene. For cases farther than twenty miles offshore this criteria is still generally valid. The units capable of accomplishing such missions are located in only a few widely separated areas.

Monte Carlo techniques are not used in this section. It consists solely of a series of programmed decision rules based upon established SAR doctrine and facilities capabilities. It provides a mission assignment for each incident to the mission simulator. (Its memory is similar to the RCC status board.)

To carry out the sample analysis in the next section of this paper, the subjective evaluation and decisions of the

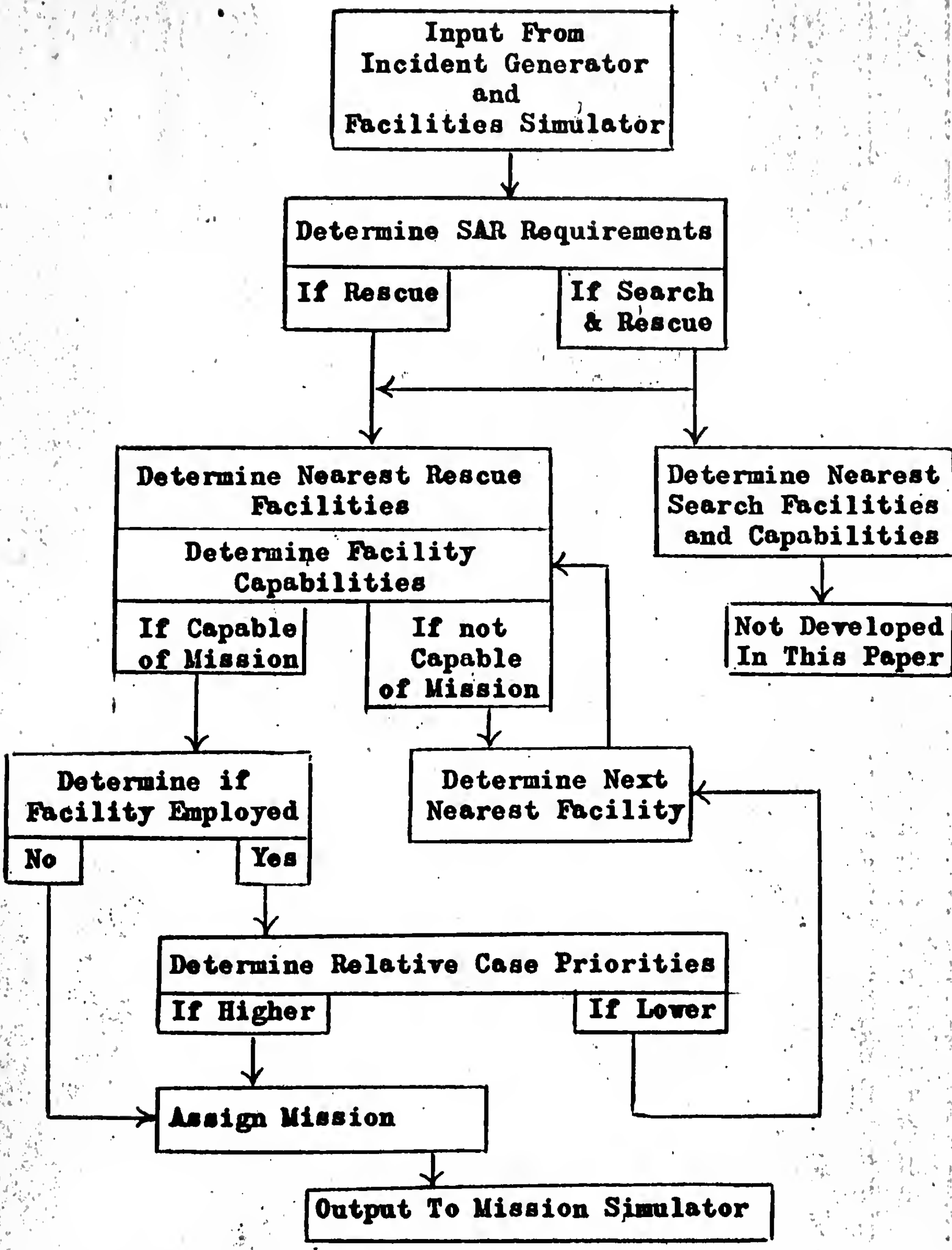


Figure 10

THE DECISION SECTION MODEL

authors are used in assigning units to missions rather than a mechanical decision program. This section of the model was not developed to a useable state.

The Mission Simulator. The mission simulator was developed only in a very simple form. This section must be designed to take the assigned unit or units and simulate their conduct of the search and rescue mission. For the purpose of the basic model shown in Figure 11, page 37, all units were considered to proceed at maximum speed, except in heavy weather. However, for added realism, all weather factors could be introduced to affect speed. The model further assumed that the required rescue action was effected upon arrival at the generated scene of the incident. The unit then returned to its home base at maximum speed unless it had a tow in which case speed was reduced accordingly.

The accomplishment of a mission was determined utilizing the SAR units as assigned in the facilities model. Arcs representing hourly distances possible for each type of unit were drawn from the applicable harbor entrances on the gridded chart. Appendix Tables XXII and XXIII, pages 79 and 80, show the distances covered by various types of vessels and aircraft. Included are delays for getting underway and clearing the harbor. In the case of aircraft, the delay to launch considered was from the first call to the time the aircraft was

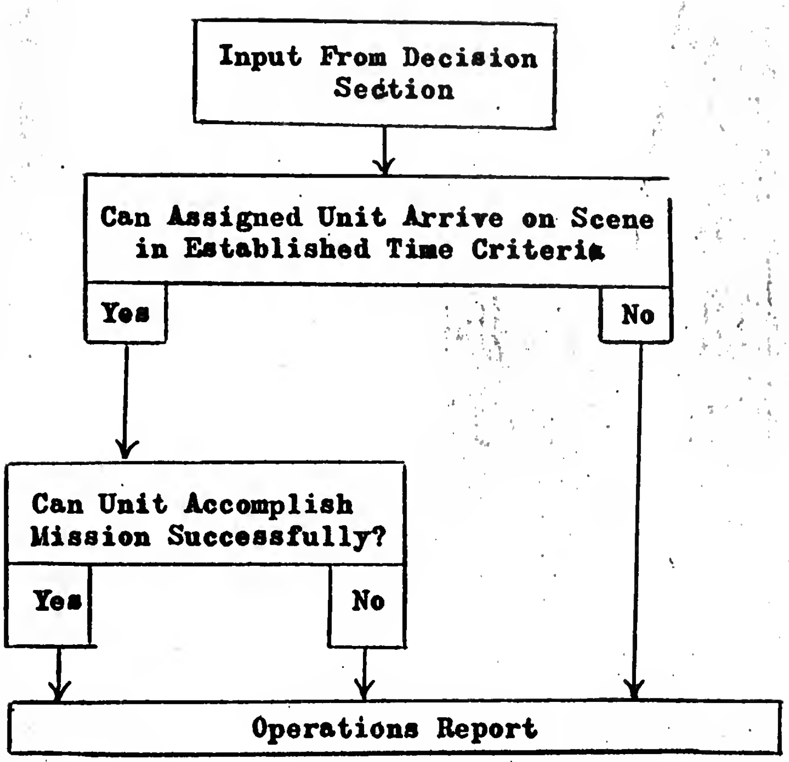


Figure 11

The Mission Simulator

airborne. The HH-52As based at San Francisco were required to refuel at Humboldt Bay before they could be effectively used in the northern areas of the District. A grid was considered covered in the time in whole hours it took for appropriate units to reach one-half of the grid. A mission was assumed completed in a satisfactory manner provided the assigned unit arrived on scene within the established time criteria set forth in Table I, page 39. For false alarms and attempted cases, facilities were committed until they arrived on scene to investigate the incident.

The definition of an effective unit varies with the case. For example, a fixed wing aircraft or a 95 foot patrol boat would not constitute an effective unit to assist a large vessel disabled but in no immediate danger. However, should the vessel founder, both would be deemed effective. The aircraft could locate the distressed vessel, drop life rafts, keep track of the survivors and vector in surface units or helicopters to effect the rescue of personnel.

A fully developed model must be extended by analysis of historical data and the application of Monte Carlo techniques to include many other variables such as the probability of success of a search; the time required for a search, perhaps on the basis of time elapsed since the incident was first reported; probabilities of poor weather making units abort

TABLE I

MAXIMUM TIME FOR EFFECTIVE UNIT TO ARRIVE ON SCENE

Type Case	Distance Offshore Less Than 20 Miles (Hours)	20-100 Miles (Hours)	Over 100 Miles (Hours)
Vessel			
Disabled	3	12	72
Foundered	1	1	5
Aground	3	-	-
Overdue	3	12	8
Medical Removal	2	3	-
Personnel	1	1	-
Aircraft Escort	-	-	3
Aircraft Crash	1	1	3
Miscellaneous	3	3	3

missions; mechanical failures that delay or prevent facilities from reaching the scene of the incident; changes in search probabilities when additional units are employed; and similar factors. To keep the model workable, the number of variables should be kept as small as possible by eliminating any that are directly related in a linear fashion. Present statistical data does not appear adequate to develop extensively this portion of the model. Estimates of critical values are often adequate for modeling purposes and will produce approximate results adequate for a relative comparison of cost effectiveness.

<u>The Model Output</u>. A fully developed comprehensive model, based upon available statistical data and reasonable assumptions when data is not available, can provide a valuable tool in analyzing the utilization of Coast Guard resources. The output section can compile and analyze operational reports and abstracts of operations for the system to determine system effectiveness. Tabulations might include lives saved, lives lost, property saved, value of property assisted, number of persons assisted, etc. Inadequate or excess facilities can be indicated and changes in SAR procedures and doctrine evaluated. It can assist in the analysis of design criteria of new equipment.

In the following chapter a sample analysis is conducted. Three alternative facilities systems are compared utilizing

the model as developed. Demonstrated are how model building techniques and Monte Carlo analysis can be applied to gain a valid comparison between the effectiveness of alternative resource distributions.

CHAPTER III

A SAMPLE ANALYSIS UTILIZING THE SAR SYSTEM MODEL

A sample analysis was conducted utilizing the model. It demonstrated the use of a model and type information one could provide. The maximum expected quantitative stress was placed on the system by choosing for study the active summer season. SAR incidents generated were based on historical frequency statistics. Three alternative resource mixes, as shown in Table II, page 43, were assumed and the incidents solved for each. Solutions were then evaluated against developed criteria. This chapter presents the methodology employed, results obtained, and an evaluation thereof.

Two summers of SAR activity were simulated by running the incident generator model twice. Table III, page 44, are the results. Although the totals are lower (370 and 379) than the observed (388), the breakdowns correlate well.

The incidents having been generated, the next step was to solve them. To do so, several assumptions had to be made and solution criteria determined. The solution criteria, while in some instances rather severe, were reasonable. For a satisfactory solution, an effective unit had to arrive within the time allotted as shown in Table I, page 39, Chapter II.

TABLE II

PRESENT AND PROPOSED ALTERNATE SAR FACILITIES
TWELFTH COAST GUARD DISTRICT

Location	Present* Type Unit	Present* Annual Op Cost	1st Alternate Type Unit	1st Alternate Annual Op Cost	2nd Alternate Type Unit	2nd Alternate Annual Op Cost
Crescent City	95'	$ 80,000	82'	$ 47,000	82'	$ 47,000
Humboldt Bay	WATF	349,000	95'	80,000	95'	80,000
	LBS#	80,000	LBS	80,000	LBS	80,000
					HH52A	100,000
Ft Bragg	82'	47,000	82'	47,000	82'	47,000
Bodega Bay	95'	80,000	82'	47,000	82'	47,000
	LBS	60,000	LBS	60,000	LBS	60,000
Pt Reyes	LBS	50,000	LBS	50,000	LBS	50,000
San Francisco	LBS	160,000	LBS	160,000	LBS	160,000
	2-OSV	0**	2-OSV	0	2-OSV	0
	2-WAGL	0**	2-WAGL	0	2-WAGL	0
	WATA	236,000	-	-	-	-
	AIRSTA	1,630,000	AIRSTA	1,480,000	AIRSTA	1,380,000
	2-C130B		2-C130B		2-C130B	
	3-HU16E		2-HU16E		2-HU16E	
	3-HH52A		3-HH52A		3-HH52A	
	COTP##		COTP		COTP	
	95'	0**	95'	0	95'	0
	82'	0**	82'	0	82'	0
	82'	47,000	-	-	-	-
	RADSTA	0**	RADSTA	0	RADSTA	0
Monterey	WSC	130,000	95'	80,000	95'	80,000
	LBS	80,000	LBS	80,000	LBS	80,000
Morro Bay	95'	80,000	95'	80,000	95'	80,000
Total		$3,109,000		$2,291,000		$2,291,000

*Cost data based on information provided by 12th CGD
**Free Good. Required for other commitments.
#Life Boat Station
##Captain of the Port

TABLE III

SIMULATED SUMMER COASTAL SAR INCIDENTS
TWELFTH COAST GUARD DISTRICT

YEAR 1

Vessels	Disabled	Foundered	Aground	Overdue	Total
Less Than 26'	83	10	5	14	112
26'–40'	62	4	12	6	84
40'–65'	39	4	8	7	58
65'–100'	5	3	0	0	8
Over 100'	10	2	3	0	15
Subtotal	199	23	28	27	277

Total Vessels	277
Medical Advice	38
Medical Removal	7
Personnel	16
Aircraft Escort	12
Aircraft Crash	6
Miscellaneous	14
Total Incidents	370

YEAR 2

Vessel	Disabled	Foundered	Aground	Overdue	Total
Less Than 26'	86	6	4	20	116
26'–40'	60	9	7	12	88
40–65'	40	3	11	7	61
65'–100'	9	1	2	0	12
Over 100'	6	4	1	0	11
Subtotal	201	23	25	39	288

Total Vessels	288
Medical Advice	33
Medical Removal	13
Personnel	10
Aircraft Escort	12
Aircraft Crash	4
Miscellaneous	19
Total Incidents	379

Sixty-one per cent of the unsatisfactory evaluations were for incidences requiring immediate assistance off the northern California coast. Assisting surface units were unable to reach the scene within the criteria limits and no Coast Guard helicopter facility was near enough to help. The criteria demanding effective units within three hours for vessels over 100 feet disabled within 20 miles of the coast was also quite difficult to meet. This became apparent when unexpectedly several cases of this type were randomly generated. The assumptions were the Coast Guard could not get an ocean going tug to sea from Humboldt Bay or San Francisco for two hours or an ocean station vessel from San Francisco for three. Other units could have been employed to standby the disabled vessel. No serious queuing was experienced either year. The case load in the approaches to San Francisco was heavy and nearing saturation. A few unsatisfactories were observed off Morro Bay when the patrol boat was engaged on one case and another occurred. In the Crescent City area a lifeboat from Brookings, Oregon in the Thirteenth Coast Guard District was required once. There is no SAR coverage that can meet the assumed criteria for the areas just south of Cape Mendocino, Point Arena, and north of Piedras Blancas. In the first summer simulated there were 370 incidents of which 341 were solved satisfactorily and 29 were not. The

second summer there were 379 incidents, 354 successful solutions, and 25 unsuccessful.

A simple alternate SAR system was then considered. It was basically the same as the existing except the medium endurance cutters and one HU-16E aircraft were omitted. This required the procurement of one 82 foot patrol boat for $360,000. Operating costs were reduced by $818,000 or 26 per cent. In the two summers there were only three additional unsatisfactory solutions. One occurred the first year and two the second. All involved vessels over 100 feet disabled. No aircraft incidents were affected.

The third alternative was a variation of the second. Number of units and their geographical assignments remained as in the second alternative except one helicopter was transferred from San Francisco to Eureka. Although the provision of suitable facilities for the helicopter at Eureka would be required, little increase in annual operating expenses was contemplated and none considered. The helicopter so reassigned was able to solve eleven additional cases the first summer and fifteen the second. All were of the type requiring immediate assistance to save life.

In searching for effectiveness criteria three sets were considered. They were number of cases successfully or unsuccessfully solved, value of units and cargo successfully or unsuccessfully assisted, and number of lives saved from or

prevented from subjection to a perilous state. The last criteria was deemed the most important and the best measure. However, it was the most difficult to compute. Personnel in a disabled, overdue, or aground vessel, as opposed to a foundering vessel, were not considered to be in immediate danger. It was possible, though, that if not assisted within a certain time the incident could deteriorate. Since the probability of this happening was not explicitly known, several approaches, including future weather, were tried. None was satisfactory. Finally, an arbitrary relationship between length of vessel and probability of imperilment was selected. Probability of situation deterioration was conservatively made inversely proportional to one-tenth the vessel length. Thus, a disabled forty foot boat not presently in extremis was assigned a probability of .25 of so becoming. Foundering vessels, medical, personnel, and miscellaneous incidents were cases requiring prompt assistance.

Tables IV through IX, on pages 48 to 53, present the results of each year's solutions for the three alternate resource allocations assumed. Tables X and XI, on pages 54 and 55, are the breakdowns of the failures. The value of property saved and number of lives saved is based upon the data provided in Appendix Table XXIV, page 81. Of particular note is the small impact of the medium endurance cutter

TABLE IV

SIMULATED SUMMER COASTAL SAR CASES
TWELFTH COAST GUARD DISTRICT
YEAR 1 - EXISTING FACILITIES

Unit Assisted	Cases	Satisfactory			Unsatisfactory		
		No	Value	Lives	No	Value	Lives
Vessel							
Less Than 26'	112	106	$ 212,000	171	6	$ 12,000	12
26'-40'	84	81	1,215,000	119	3	45,000	4
40'-65'	58	57	2,280,000	83	1	40,000	6
65'-100'	8	7	2,100,000	26	1	300,000	10
Over 100'	15	9	18,000,000	94	6	12,000,000	12
Medical							
Advice	38	38	-	38	0	-	0
Removal	7	4	-	4	3	-	3
Personnel	16	9	-	18	7	-	14
Aircraft							
Escort	12	12	24,000,000	600	0	0	0
Crash	6	6	- *	300	0	-	0
Miscellaneous	14	12	60,000	24	2	10,000	4
Total	370	341	$47,867,000	1,477	29	$12,407,000	65

*No value inasmuch as Coast Guard activities cannot usually salvage downed aircraft.

TABLE V

SIMULATED SUMMER COASTAL SAR CASES
TWELFTH COAST GUARD DISTRICT
YEAR 1 - FIRST ALTERNATE

Unit Assisted	Cases	Satisfactory No	Satisfactory Value	Satisfactory Lives	Unsatisfactory No	Unsatisfactory Value	Unsatisfactory Lives
Vessel							
Less Than 26'	112	106	212,000	171	6	$ 12,000	12
26'-40'	84	81	1,215,000	119	3	45,000	4
40'-65'	58	57	2,280,000	83	1	40,000	6
65'-100'	8	7	2,100,000	26	1	300,000	10
Over 100'	15	8	16,000,000	92	7	14,000,000	14
Medical							
Advice	38	38	-	38	0	-	0
Removal	7	4	-	4	3	-	3
Personnel	16	9	-	18	7	-	14
Aircraft							
Escort	12	12	24,000,000	600	0	-	0
Crash	6	6	- *	300	0	-	0
Miscellaneous	14	12	60,000	24	2	10,000	4
Total	370	340	$45,867,000	1,475	30	$14,407,000	67

*No value inasmuch as Coast Guard activities cannot usually salvage downed aircraft.

TABLE VI

SIMULATED SUMMER COASTAL SAR CASES
TWELFTH COAST GUARD DISTRICT
YEAR 1 - SECOND ALTERNATE

Unit Assisted	Cases	Satisfactory			Unsatisfactory		
		No	Value	Lives	No	Value	Lives
Vessel							
Less than 26'	112	108	$ 216,000	177	4	$ 8,000	6
26'-40'	84	81	1,215,000	119	3	45,000	4
40'-65'	58	58	2,320,000	89	0	-	0
65'-100'	8	8	2,400,000	36	0	-	0
Over 100'	15	8	16,000,000	92	7	14,000,000	14
Medical							
Advice	38	38	-	38	0	-	0
Removal	7	7	-	7	0	-	0
Personnel	16	13	-	26	3	-	6
Aircraft							
Escort	12	12	24,000,000	600	0	-	0
Crash	6	6	- *	300	0	-	0
Miscellaneous	14	12	60,000	24	2	10,000	4
Total	370	348	$46,211,000	1508	19	$14,063,000	34

*No value inasmuch as Coast Guard activities cannot usually salvage downed aircraft.

TABLE VII

SIMULATED SUMMER COASTAL SAR CASES
TWELFTH COAST GUARD DISTRICT
YEAR 2 - EXISTING FACILITIES

		Satisfactory			Unsatisfactory		
Unit Assisted	Cases	No	Value	Lives	No	Value	Lives
Vessel							
Less than 26'	116	110	$ 220,000	171	6	$ 12,000	12
26'-40'	88	85	1,275,000	132	3	45,000	9
40'-65'	61	58	2,320,000	79	3	120,000	8
65'-100'	12	10	3,000,000	13	2	600,000	11
Over 100'	11	11	22,000,000	174	0	-	0
Medical							
Advice	33	33	-	33	0	-	0
Removal	13	8	-	8	5	-	5
Personnel	10	7	-	14	3	-	6
Aircraft							
Escort	12	12	24,000,000	600	0	0	0
Crash	4	3	- *	150	1	-	50
Miscellaneous	19	17	85,000	34	2	10,000	4
Total	379	354	$52,900,000	1408	25	$ 787,000	105

*No value inasmuch as Coast Guard activities cannot usually salvage downed aircraft.

TABLE VIII

SIMULATED SUMMER COASTAL SAR CASES
TWELFTH COAST GUARD DISTRICT
YEAR 2 - FIRST ALTERNATE

Unit Assisted	Cases	Satisfactory			Unsatisfactory		
		No	Value	Lives	No	Value	Lives
Vessel							
Less Than 26'	116	110	$ 220,000	171	6	$ 12,000	12
26'-40'	88	85	1,275,000	132	3	45,000	9
40'-65'	61	58	2,320,000	79	3	120,000	8
65'-100'	12	10	3,000,000	13	2	600,000	11
Over 100'	11	9	18,000,000	170	2	4,000,000	4
Medical							
Advice	33	33	-	33	0	-	0
Removal	13	8	-	8	5	-	5
Personnel	10	7	-	14	3	-	6
Aircraft							
Escort	12	12	24,000,000	600	0	0	0
Crash	4	3	- *	150	1	-	50
Miscellaneous	19	17	85,000	34	2	10,000	4
Total	379	352	$48,900,000	1404	27	4,787,000	109

*No value inasmuch as Coast Guard activities cannot usually salvage downed aircraft.

TABLE IX

SIMULATED SUMMER COASTAL SAR CASES
TWELFTH COAST GUARD DISTRICT
YEAR 2 - SECOND ALTERNATE

Unit Assisted	Cases	Satisfactory			Unsatisfactory		
		No	Value	Lives	No	Value	Lives
Vessel							
Less Than 26'	116	112	$ 224,000	177	4	$ 8,000	6
26'-40'	88	87	1,305,000	140	1	15,000	1
40'-65'	61	59	2,360,000	85	2	80,000	2
65'-100'	12	10	3,000,000	13	2	600,000	11
Over 100'	11	9	18,000,000	170	2	4,000,000	4
Medical							
Advice	33	33	-	33	0	-	0
Removal	13	13	-	13	0	-	0
Personnel	10	10	-	20	0	-	0
Aircraft							
Escort	12	12	24,000,000	600	0	0	0
Crash	4	4	- *	200	0	-	0
Miscellaneous	19	17	85,000	34	2	10,000	4
Total	379	366	$48,974,000	1485	13	$4,713,000	28

*No value inasmuch as Coast Guard activities cannot usually salvage downed aircraft.

TABLE X

SIMULATED COASTAL SUMMER SAR CASES - YEAR 1
SOLUTIONS NOT MEETING THE CRITERIA
TWELFTH COAST GUARD DISTRICT

Less Than 20 Miles Offshore	Type	Nature	Present Facilities	Alternatives 1st	Alternatives 2nd
Crescent City	Over 100'	Disabled	1	1	1
	Medical Removal		1	1	0
	Personnel		2	2	0
Trinidad Head	65'-100'	Foundered	1	1	0
	Personnel		1	1	0
Eureka	Less Than 26'	Foundered	2	2	0
	40'-65'	Foundered	1	1	0
	Medical Removal		1	1	0
Cape Mendocino	Less Than 26'	Disabled	2	2	2
	Personnel		1	1	0
Cape Vizcarno	Medical Removal		1	1	0
Pt Cabrillo	Personnel		2	2	2
Pt Arena	26'-40'	Disabled	1	1	1
Bodega Bay	Over 100'	Disabled	1	1	1
Farallons	Over 100'	Disabled	4	4	4
Santa Cruz	Over 100'	Disabled	0	1	1
Piedras Blancas	Less Than 26'	Disabled	1	1	1
	26'-40'	Aground	1	1	1
	Personnel		1	1	1
	Miscellaneous		2	2	2
Morro Bay	Less Than 26'	Disabled	1	1	1
	26'-40'	Disabled	1	1	1
Total			29	30	19

TABLE XI

SIMULATED COASTAL SUMMER SAR CASES - YEAR 2
SOLUTIONS NOT MEETING THE CRITERIA
TWELFTH COAST GUARD DISTRICT

Area	Type	Nature	Present Facilities	Alternatives 1st	Alternatives 2nd
Less Than 20 Miles	Offshore				
Crescent City	Personnel		1	1	0
	Medical Removal		1	1	0
Trinidad Head	Less Than 26'	Foundered	2	2	0
Eureka	26'-40'	Foundered	2	2	0
	40'-65'	Foundered	1	1	0
	Medical Removal		2	2	0
	Personnel		2	2	0
	Aircraft	Crash	1	1	0
Cape Mendocino	Less Than 26'	Disabled	1	1	1
	26'-40'	Disabled	1	1	1
	Medical Removal		1	1	0
Pt Delgada	Medical Removal		1	1	0
Pt Arena	Miscellaneous		1	1	1
Monterey	Over 100'	Disabled	0	1	1
Piedras Blances	Less Than 26'	Disabled	3	3	3
	40'-65'	Aground	1	1	1
	40'-65'	Disabled	1	1	1
	65'-100'	Foundered	1	1	1
	Miscellaneous		1	1	1
Morro Bay	65'-100'	Disabled	1	1	1
20-100 Miles	Offshore				
Northern Calif	Over 100'	Disabled	0	1	1
Total			25	27	13

removal from the summer scene. Provided high endurance cutters are required for the Ocean Station Program and seagoing buoy tenders are based in San Francisco, no need was indicated for any medium endurance cutter in the Twelfth Coast Guard District. Although the alternative was not investigated, a medium endurance cutter in Humboldt Bay might be justifiable. The more severe environmental conditions and long coastline without a vessel of comparable characteristics make such an assignment seem reasonable.

The establishment of a helicopter facility in northern California promises the highest returns of any alternative in lives potentially saved. Under the conditions herein assumed, the number of lives preserved from peril would be reduced by well over half.

Analysis, such as the one discussed in this chapter, could be extended to include all aspects of the search and rescue problem.

CHAPTER IV

SUMMARY AND CONCLUSIONS

This paper develops a methodology for analysis rather than any recommendations or conclusions as to the effectiveness of present facilities. Throughout the construction and use of the SAR model it was evident that useful information can be gained through model building and Monte Carlo techniques even though the model employed is an elementary one. The process of model building has a large intrinsic value in forcing the decision maker to view the interaction among parameters explicitly. Relationships implied by subjective judgment often lose their validity when viewed in the cold light of analysis. For instance, the present medium endurance cutter was once considered a major work horse of the SAR team. Under present maritime traffic conditions its contribution to total SAR system effectiveness appears to be questionable when analyzed within the parameters of the model.

Limitations of Model. Since cases were only generated and evaluated for two summer periods, the results cannot be given the confidence normally expected from long run averages. Without computerization of the model, the manipulation of variables was limited to three simple alternatives. However,

even with such an elementary change, the value of helicopter coverage in the Eureka area is evident.

This limited model also points up the need for not neglecting the rare event of disaster to the large vessel. The lives and property in jeopardy are large and, on a lives-property basis, equal many small craft incidents. The alternatives also show that changes in resources mixes and location can produce an effectiveness which results in more lives saved but more property lost. Since the saving of life is paramount, the increase in property loss level is not considered significant.

As solutions of the SAR incidents progressed it became evident that a solution evaluation criteria depending on effective rescue units reaching the distress scene within an allotted time was not realistic. The ability to overcome disaster or provide a useful degree of self sustainment until assistance arrives is some function of the size of a vessel. It may be argued that this is an incommensurable parameter to be disregarded. However, the model used one-tenth of the vessel length in order to arrive at a probability. A reasonable measure introduced into the model is better than ignoring the situation since many decisions in the real world are often based on intuition alone. Further, the model can be operated with various measures and the results analyzed.

If this produces significant changes in effectiveness, then it should prove practical to expend resources in order to determine which set of probabilities most closely approximate the real world.

Data on extraordinary local conditions was not available and not considered. This could be a significant factor. Reports of assistance should include notations to this effect. The model could then be modified to account for its effect both on producing the incident and influencing rescue operations and resource allocations. To some extent, this has been recognized by the placement of special motor life boats in the Eureka area.

The model shows a need for better abstraction of information from the assistance reports which are submitted to the District. Too much attention is given to totals and averages rather than to analysis and distributions of events. For example, there is no distribution of the units' time underway. Totals and averages are available but these tell nothing about the percentage of cases of say, three, five or seven hours' duration. Without this, it is difficult to ascertain the minimum number of units required to reduce queuing and the assignment of resources is based on other factors.

Analysis showed that weather was about the same in the three areas (north, central and south) during the peak summer season. However, this is not true during the other times of the year. A different distribution for both weather and incidents must be used when other seasons are considered. This points up the fallacy of using averages.

Further Use of Model Building for Coast Guard Analysis. Analysis of the SAR system within the frame work of the present model, or a more sophisticated version, could be extended to other areas such as facilities design requirements, boating population trends and SAR doctrine. The design of any section of the model can be altered to see what effect changes would have on system costs and effectiveness. For example, the case simulator could be modified to show an increased density of pleasure craft spread out along the entire California coast. This change is realistic considering the Harbors of Refuge being developed by the State of California and the forecasted growth of the boating population in the immediate future [7]. How effectively can present resources handle the change in SAR requirements that this will bring?

After modifying the incident generator to consider this population growth, and present facilities are evaluated,

the facilities section could be modified by reallocation of present facilities within the area to determine if an alternate system could provide more effective coverage at the same costs. Alternate types of facilities could be distributed along the Harbors of Refuge to see what combination of units would provide the optimum cost effectiveness for the system. Decision makers would be better able to formulate long range plans to accomplish the changing missions of the service.

The effects of certain types of units upon total system effectiveness could be evaluated. Could the two $125,000 forty-four foot motor life boats provide greater total system effectiveness than one $250,000 fifty-two foot motor life boat? What change in effectiveness would result in substituting a $45,000 forty-foot utility boat for a $125,000 motor life boat? Could the savings in cost provide a greater increment of total effectiveness when utilized for other resources?

The contributions to system effectiveness of proposed new types of facilities could be analyzed through sophisticated models. Presently the operational capabilities and effectiveness of the new medium endurance cutter-helicopter team is untried. The procurement of this equipment is based on experience and subjective judgment. The SAR model

could be programmed to include this resource. Based upon the design data, it could develop the expected contribution to system effectiveness. The same model could evaluate alternative locations for new types of facilities as well as evaluate facilities performance.

Even greatly simplified models based upon approximate data can give valid answers to questions of this nature. These are the types of questions which must be asked and answered by decision makers if optimum utilization of our resources is to be achieved. The scope of the model can be modified to suboptimize specific areas such as the requirement for coverage in Monterey Bay for small craft protection or that for large vessels for extended operations.

<u>Areas for Further Study</u>. More sophisticated studies of this nature are required to develop usable models and valid analysis of various Coast Guard activities in order to provide answers to questions such as those discussed above.

No studies or analysis conducted of Coast Guard activities can provide a fully usable decision making tool until an improved measure of effectiveness is developed. Future studies should include the following parameters and their interactions in any attempt to construct an improved measure of effectiveness:

1. Lives lost.
2. Lives saved.
3. Lives in jeopardy.
4. Property lost.
5. Property saved.
6. Property in jeopardy.
7. Capability of vessels in jeopardy, such as firefighting capacity, compartmentation, and safety equipment.
8. Degree of peril.

The original measure of effectiveness used in this paper was cases solved. This was refined to lives and value of property saved. The next step toward an improved measure appears to be a relationship to provide for the combining of the number of lives and the value of property into a single measure.

Conclusions. Analysis using the methodology developed in this paper can provide valid answers for high level decision makers. With refinement and computerization, models and Monte Carlo methods become a useful decision makers' tool. The Coast Guard has long been operating on experience and intuitive judgment. A career officer spends less than one-third of his time at sea. The service no longer has the experienced man operating at sea from whom to obtain mature judgment. As technology increases man's ability to survive at sea, it also complicates the decision making process and makes wrong decision more costly. It is therefore imperative that decision making tools such

as Model Building and Monte Carlo methods be developed. The basic tools are available and can be applied by most Coast Guard officers.

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APPENDIX

TABLE XII

ENVIRONMENTAL CONDITIONS SUMMARY

TWELFTH COAST GUARD DISTRICT

JULY - SEPTEMBER

Subarea	Relative Size	Wgt	Fog Freq	Expected Fog Freq	Small Craft Warnings Freq	Expected Small Craft Warnings Freq
Northern	2	.4	.349	.140	.036	.014
Central	2	.4	.289	.116	.011	.004
Southern	1	.2	.296	.059	.005	.001
		1.0		.315		.019

Sea Condition Frequencies

Subarea	Wgt	Calm	Expected	1-11 Feet	Expected	Over 11 Feet	Expected
Northern	.4	.32	.128	.63	.252	.05	.020
Central	.4	.28	.112	.68	.272	.04	.016
Southern	.2	.30	.060	.67	.134	.03	.006
	1.0		.300		.658		.042

Assumed Distributions

Avg Visability	Freq	RN Range	Avg Sea Condition	Freq	RN Range
Fog	.32	01-32	0-3 Feet	.60	01-60
Clear	.68	33-00	3-10 Feet	.36	61-96
			Over 10 Feet	.04	97-00

TABLE XIII

CASES PER DAY

Weekday	Poisson Distribution	Mean of 3.3
Number of Cases or Less	Cumulative Probability	RN Range
0	.04	01–04
1	.18	05–18
2	.35	19–35
3	.57	36–57
4	.75	58–75
5	.88	76–88
6	.95	89–95
7	.98	96–98
8	.99	99
9	1.00	00

Weekend	Poisson Distribution	Mean of 6.6
Number of Cases or Less	Cumulative Probability	RN Range
1	.01	01
2	.04	02–04
3	.10	05–10
4	.20	11–20
5	.35	21–35
6	.51	36–51
7	.65	52–65
8	.78	66–78
9	.86	79–86
10	.93	87–93
11	.96	94–96
12	.98	97–98
13	.99	99
14	1.00	00

TABLE XIV

TIME OF INCIDENT

Time	Percent of Incidents	RN Range
00–06	15	01–15
06–12	20	16–35
12–18	40	36–75
18–24	25	76–00

TABLE XV

COASTAL CASES FIRST AND SECOND QUARTERS FY 64 (44.6%)
TWELFTH COAST GUARD DISTRICT

	July-Sept		Oct-Dec		Total	
	Cases	% of Coastal	Cases	% of Coastal	Cases	% of Coastal
Crescent City	12	3.1	2	0.9	14	2.3
Klamath River	32	8.2	1	0.5	33	5.4
Humboldt Bay	39	10.0	15	6.8	54	8.9
Ft Bragg	18	4.6	5	2.3	23	3.8
Pt Arena	3	0.8	0	0.0	3	0.5
Bodega	34	8.8	15	6.8	49	8.1
Pt Reyes	27	7.0	15	6.8	42	6.9
SFran Approach	58	14.9	33	15.0	91	15.0
Half Moon Bay	19	4.9	9	4.1	28	4.6
Monterey	63	16.2	41	18.6	104	17.1
Morro Bay	23	5.9	21	9.5	44	7.2
Offshore	60	15.5	63	28.6	123	20.2
Total	388	99.9	220	100.1	608	100.0

Broad Area	July-Sept		Oct-Dec		Total	
	Cases	% of Coastal	Cases	% of Coastal	Cases	% of Coastal
13th CGD Line to Pt Arena	104	26.8	23	10.5	127	20.9
Pt Arena to Pt Sur	201	51.8	113	51.4	314	51.7
Pt Sur to 11th CGD Line	23	5.9	21	9.5	44	7.2
Offshore	60	15.5	63	28.6	123	20.2
Total	388	99.9	220	100.0	608	100.0

TABLE XVI

COASTAL CASES FIRST AND SECOND QUARTERS FY 64 (44.6%)
TWELFTH COAST GUARD DISTRICT

	July-Sept		Oct-Dec		Total	
	Cases	% of Area	Cases	% of Area	Cases	% of Coastal
Crescent City	12	86	2	14	14	2.3
Klamath River	32	97	1	3	33	5.4
Humboldt Bay	39	72	15	28	54	8.9
Ft Bragg	18	78	5	22	23	3.8
Pt Arena	3	100	0	0	3	.5
Bodega	34	69	15	31	49	8.1
Pt Reyes	27	64	15	36	42	6.9
SFran Approach	58	64	33	36	91	15.0
Half Moon Bay	19	68	9	32	28	4.6
Monterey	63	62	41	38	104	17.1
Morro Bay	23	52	21	48	44	7.2
Offshore	60	49	63	51	123	20.2
Total	388	64	220	36	608	100.0

Broad Area	July-Sept		Oct-Dec		Total	
	Cases	% of Area	Cases	% of Area	Cases	% of Coastal
13th CGD Line to Pt Arena	104	82	23	18	127	20.9
Pt Arena to Pt Sur	201	64	113	36	314	51.7
Pt Sur to 11th CGD Line	23	52	21	48	44	7.2
Offshore	60	49	63	51	123	20.2
Total	388		220		608	100.0

TABLE XVII

COASTAL SAR CASE BREAKDOWN FIRST AND SECOND QUARTERS FY 64
TWELFTH COAST GUARD DISTRICT

Geographic Area Distance Offshore	Geographic Area Latitude Range	Jul to Dec Cases	% Jul to Sept Cases	Jul to Sept Cases	Jul to Sept Area %	Grid	Random Number Range From	Random Number Range To
Less Than 20 Miles	41.5–42.0	29	86	25	6.4	N1	001	064
	41.0–41.5	22	97	21	5.4	N2	065	118
	40.5–41.0	41	72	29	7.4	N3	119	192
	40.0–40.5	7	80	6	1.5	N4	193	207
	39.5–40.0	24	80	19	4.9	N5	208	256
	39.0–39.5	19	80	15	3.8	N6	257	294
20–100 Miles	39.0–42.0	5	49	2	.5	N21	295	299
Over 100 Miles	39.0–42.0	19	49	9	2.3	N101	300	322
Less Than 20 Miles	38.5–39.0	1	100	1	.3	C1	323	325
	38.0–38.5	49	69	34	8.7	C2	326	412
	37.5–38.0	154	64	98	25.2	C3	413	664
	37.0–37.5	17	64	11	2.8	C4	665	692
	36.5–37.0	63	62	39	10.0	C5	693	792
	36.0–36.5	14	62	9	2.3	C6	793	815
20–100 Miles	36.0–39.0	13	49	6	1.5	C21	816	830
Over 100 Miles	36.0–39.0	18	49	9	2.3	C101	831	853
Less Than 20 Miles	35.5–36.0	3	52	2	.5	S1	854	858
	35.0–35.5	39	52	20	5.2	S2	859	910
	34.5–35.0	3	52	2	.5	S3	911	915
20–100 Miles	34.5–36.0	7	49	3	.8	S21	916	923
Over 100 Mile Line	–36.0	61	49	30	7.7	S101	924	000
Total		608		390	100.0			

TABLE XVIII

COASTAL SAR CASE DISTRIBUTION FIRST AND SECOND QUARTERS FY 64
TWELFTH COAST GUARD DISTRICT

Unit Assisted	Cases	%	Less than 20 Miles Cases	%	20-100 Miles Cases	%	Over 100 Miles Cases	%
Vessels								
Less than 26'	157	26	157	26	0	0	00	0
26' to 40'	115	19	115	19	0	0	0	0
40' to 65'	110	18	94	15	12	2	4	1
65' to 100'	22	4	12	2	6	1	4	1
Over 100'	22	4	10	2	2	0	10	2
Aircraft	32	5	5	1	0	0	27	4
Medical								
Radio Advice	75	12	24	4	0	0	51	8
Removal	19	3	15	2	4	1	0	0
Personnel Only	25	4	25	4	0	0	0	0
Miscellaneous	31	5	28	5	1	0	2	0
Total	608	100	485	80	25	4	98	16

TABLE XIX

COASTAL SAR CASE DISTRIBUTION FIRST QUARTER FY 64

TWELFTH COAST GUARD DISTRICT

Unit Assisted	Cases	%	Less than 20 Miles Cases	%	20-100 Miles Cases	%	Over 100 Miles Cases	%
Vessel								
Less than 26'	120	31	120	31	0	0	0	0
26' to 40'	87	22	87	22	0	0	0	0
40' to 65'	60	15	52	13	6	2	2	1
65' to 100'	11	3	6	2	3	1	2	1
Over 100'	11	3	5	1	1	0	5	1
Aircraft	16	4	2	1	0	0	14	4
Medical								
Radio Advice	39	10	14	4	0	0	25	6
Removal	11	3	9	2	2	0	0	0
Personnel Only	15	4	15	4	0	0	0	0
Miscellaneous	18	5	17	4	0	0	1	0
Total	388	100	327	84	12	3	49	13

TABLE XX

COASTAL SAR CASE DISTRIBUTION SECOND QUARTER FY 64

TWELFTH COAST GUARD DISTRICT

Unit Assisted	Cases	%	Less than 20 Miles Cases	%	20-100 Miles Cases	%	Over 100 Miles Cases	%
Vessel								
Less than 26'	37	17	37	17	0	0	0	0
26' to 40'	28	13	28	13	0	0	0	0
40' to 65'	50	23	42	19	6	3	2	1
65' to 100'	11	5	6	3	3	1	2	1
Over 100'	11	5	5	3	1	0	5	2
Aircraft	16	7	3	1	0	0	13	6
Medical								
Radio Advice	36	16	10	4	0	0	26	12
Removal	8	4	6	3	2	1	0	0
Personnel Only	10	4	10	4	0	0	0	0
Miscellaneous	13	6	11	5	1	0	1	0
Total	220	100	158	72	13	6	49	22

TABLE XXI

NATURE OF DISTRESS - VESSELS AND AIRCRAFT
TWELFTH COAST GUARD DISTRICT
JULY - SEPTEMBER

Length	Disabled	Overdue	Aground	Foundered	Total
Vessels Less Than 20 Miles Offshore					
Less than 26'	89	16	7	8	120
26–40'	62	9	12	4	87
40–65'	38	4	7	3	52
65–100'	3	0	2	1	6
Over 100'	4	0	1	0	5
Subtotal	196	29	29	16	270
Vessels 20 to 100 Miles Offshore					
40–65'	3	2	0	1	6
65–100'	2	0	0	1	3
Over 100'	1	0	0	0	1
Subtotal	6	2	0	2	10
Vessels Over 100 Miles Offshore					
40–65'	1	1	0	0	2
65–100'	2	0	0	0	2
Over 100'	3	0	0	2	5
Subtotal	6	1	0	2	9
Grand Total	208	32	29	20	289

Distance Offshore	Aircraft Escort	Crash	Total
Less than 20 Miles	0	2	2
20–100 Miles	0	0	0
Over 100 Miles	13	1	14
Total	13	3	16

TABLE XXII

VESSEL CAPABILITIES

Type Vessel	Time to Clear Harbor (Hours)	SOA	Miles From Harbor Entrance 1 Hr	2 Hr	3 Hr	4 Hr
25'	.5	6	3	9	15	-
30'	.5	20	10	30	50	-
36'	.5	8	4	12	20	-
40'	.5	20	10	30	50	-
44'	.5	16	8	24	40	-
82'	1.0	20	0	20	40	60
95'	1.0	18	0	18	36	54
125'	1.0	12	0	12	24	36
WATA-WAGL	2.0	12	0	0	12	24
WATF	2.0	15	0	0	15	30
WAVP-WPG	3.0	17	0	0	0	17

TABLE XXIII

AIRCRAFT CAPABILITIES

Type	Time To Launch	Speed	Miles From San Francisco 1 Hr	2 Hr	3 Hr	4 Hr
HC 130 B	15 min	280	210	350	490	770
HU 16 E	15 min	180	135	225	315	495
HH 52 A	15 min	90	70	115	160	-

TABLE XXIV

ESTIMATE OF PROPERTY VALUE AND PERSONNEL PER INCIDENT

Incident	Value	Lives
Vessels		
Less than 26'	$ 2,000	3
26' - 40'	15,000	4
40'-65'	40,000	6
65'-100'	300,000	10
Over 100'	2,000,000	40
Aircraft	2,000,000	50
Medical		
Advice	-	1
Removal	-	1
Personnel	-	2
Miscellaneous	5,000	2